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Full Length Research Article

ANTIMICROBIAL ACTIVITIES, GC-MS COMPOSITION AND PROXIMATE ANALYSIS OF VOLATILE OIL EXTRACT FROM TUMERIC RHIZOMES *(CURCUMA LONGA)*

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ABSTRACT
This research investigated the antimicrobial activity, GC-MS, and proximate composition of turmeric rhizomes (Curcuma longa) using standard methods. The results showed turmeric contained crude protein (8.12%), lipid (5.75%), fiber (5.00%), ash (6.50%), moisture (10.20%), and carbohydrate (64.43%). Oil was extracted via the AOAC method using n-hexane. FTIR analysis identified functional groups, including OH, CH3, C=O, and C=C, within a wavenumber range of 4000–650 cm^{-1}. UV-Visible analysis revealed a peak at 415 nm, indicating conjugated systems and aromatic compounds. GC-MS identified 19 compounds, with turmerone and curlone being prominent, known for antibacterial, antioxidant, anti-inflammatory, and anti-cancer properties. Antimicrobial testing showed turmeric oil's significant effectiveness against *Staphylococcus aureus*, *Pseudomonas sp.*, and *Aspergillus sp.* at varying concentrations.

Keywords: Turmeric rhizomes, Curcuma longa, Turmerone, Curlone, Antimicrobial activity, *Staphylococcus aureus*, *Pseudomonas sp.*, *Aspergillus sp*.

1.0 INTRODUCTION

Essential oils can be defined as a concentrated, hydrophobic liquid containing volatile aroma compounds from plants (Mamusa *et al*., 2021). The study of essential oils reveals their longstanding use across cultures, including ancient Rome, Greece, Egypt, and the Far and Middle East, for various purposes like perfumes, cosmetics, deodorants, food flavorings, and medicinal uses (Guye and Dabaro, 2021). By the 16th century, the study of essential oils had advanced significantly, leading to the growth of markets focused on these oils (Cotte *et al*., 2019). Modern distillation technology has transformed essential oils into valuable industrial raw materials with applications in creating specific flavors and aromas (Rettberg *et al*., 2018). Defined as concentrated liquids rich in volatile aromatic compounds, essential oils are widely used today in various products such as perfumes, lotions, food preservatives, and medicines (Mamusa *et al*., 2021).

Turmeric (Curcuma longa), a Zingiberaceae family member native to South Asia, is well known for its medicinal and culinary properties. The plant thrives in tropical climates and is valued for its bioactive compounds that provide health benefits, a distinct color, and flavor (Hunter, 2018; Chanda and Ramachandra, 2019). In Nigeria, turmeric grows at various altitudes and is culturally significant, with local names varying across regions (Nwankwo *et al*., 2023; Enemor *et al*., 2020). Turmeric rhizomes are commonly used to treat ailments such as malaria, jaundice, skin diseases, and arthritis. They are believed to have anticancer, antidiabetic, antioxidant, anti-inflammatory, antimicrobial, and hepatoprotective effects (Ayati *et al*., 2019; Chanda and Ramachandra, 2019).

Curcumin, the principal curcuminoid in turmeric, is a well-researched compound known for its antioxidant, anti-inflammatory, and anticancer properties (Sharifi-Rad *et al*., 2020). Studies continue to explore its clinical applications and mechanisms of action, driven by its promising therapeutic potential.

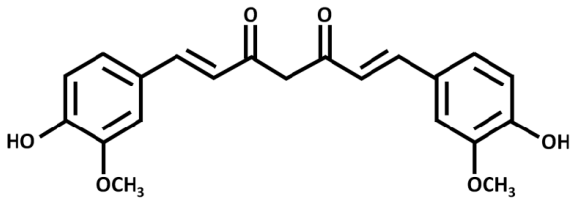

Figure 1: Shows the structure of Curcumin

Turmeric essential oil, extracted from the rhizomes, is another valuable component of the plant. This oil is composed of various aromatic compounds, including terpenes, sesquiterpenes, and phenolic compounds. These compounds contribute to the oil's characteristic aroma and may also possess bioactive properties (Ray *et al*., 2022). These compounds not only infuse turmeric with its aromatic allure but also hold potential bioactivities (Kumar *et al*., 2024).

Beyond its bioactive compounds, turmeric's nutritional composition is of interest. Proximate analysis, a standard method for determining the nutritional content of plant materials, offers insights into moisture content, ash content, lipid (fat) content, protein content, and carbohydrate content. Understanding the nutritional profile of turmeric oil extract contributes to its potential applications in functional foods and nutraceuticals (El-Saadony *et al*., 2023).

Gas Chromatography-Mass Spectrometry (GC-MS) is a widely used analytical technique to identify and quantify the constituents of essential oils. It has been successfully employed to analyze the volatile compounds in various plant extracts, enabling the identification of specific compounds and their potential effects (Lubes, 2017). GC-MS analysis of turmeric essential oil has revealed the presence of compounds such as α-turmerone, β-turmerone, and ar-turmerone, each with its own potential bioactivity (Kumar *et al*., 2024).

Enemor *et al*. (2020), studied the Evaluation of the Nutritional Status and Phytomedicinal Properties of Dried Rhizomes of Turmeric (*Curcuma longa*). Using standard methods (High

Performance Liquid Chromatography, Gas Chromatography-Mass Spectroscopy and Atomic Absorption Spectrophotometry), the dried rhizomes were washed, pulverized and ethanol extracts subjected to proximate, phytochemical, vitamins, amino acid and mineral determinations. Data obtained were analyzed using student's t-test in Statistical Package for the Social Sciences version. Determined proximate indices indicated moisture content of 9.55 %, carbohydrate (57.30 %), ash (24.70 %), crude fiber (1.12 %), proteins (2.15 %) and fat (5.32 %). Mineral composition analyses showed that *C. longa* rhizomes had higher contents of calcium, magnesium, potassium and sodium in parts per million (ppm) at 38.68 ± 0.114, 19.75 ± 0.001, 9.20 ± 0.002 and 7.06 ± 0.014 respectively. Amino acid profile revealed the presence of both essential and non-essential types with aspartate and glutamate in higher contents at 9.78 g/100 g and 9.65 g/100 g, respectively. Findings showed also the presence of vitamins A, C and D at 254.5 ± 2.19 mg/kg, 19.47 ± 0.16 mg/kg and 10.92 ± 0.92 mg/kg, respectively. Phytochemical analyses showed the presence of phenolic compounds with high retention times.

Dessy *et al.* (2017), analyze and characterize the chemical composition of the different crude extracts from the rhizome of Curcuma aeruginosa Roxb a medicinal plant. The air-dried rhizomes were powdered and subjected to Soxhlet extraction using solvent n-hexane and Supercritical fluid extraction. Then, each of the extracts were further subjected to gas chromatography-mass spectrometry. Qualitative determination of the different biologically active compounds from crude extracts of C aeruginosa Roxb using gas chromatography–mass spectrometry revealed different types of high and low molecular weight chemical entities with varying quantities present in each of the extracts.

Anabrisa *et al.* (2020), evaluate the variability in the percentage and the chemical composition of volatile oils from 12 turmeric samples. Rhizomes of the turmeric plant were collected from three different producers in the Brazilian like savanna (Cerrado) habitat in the state of Bahia. The chemical composition of the oils derived from the rhizomes was analysed by thin-layer chromatography and GC-MS. The average oil content was 3.97 % ± 0.61 %, varying from 3.0 % to 5.16 %. There were differences between producers; however, all samples met the specification of the Brazilian Pharmacopoeia. Thin-layer chromatographic analysis revealed qualitative similarity in both oil and curcuminoid components among the samples.

Prakash *et al.* (2015), studied the GC-MS Analysis of Essential Oil of Turmeric Rhizome and its Activity Against Sporothrix schenckii Fungus. The volatile oil of turmeric (Curcuma longa) was isolated from its rhizomes through steam distillation. Oil thus obtained was analysed by GS-MS technique. The oil showed 20 constituents of which, 6 components contributing 70 % of the total composition.

Naz *et al.* (2010), studied the chemical analysis of essential oils from turmeric (*Curcuma longa*) rhizome through GC-MS. The volatile oil of turmeric (*Curcuma longa* L., zingiberaceae) was isolated from its rhizomes. Gas chromatography-mass spectrometry (GC- MS) was applied to the methanolic extract of *C. longa*. The Chromato- graphic analysis of oil showed 16 constituents of which, 6 compounds contributing 70.0 % of the total oil constituents could be identified.

Enemoh *et al.* (2020), studied on Evaluation of the nutritional status and phytomedicinal properties of dried rhizomes of turmeric (Curcuma longa). Turmeric Rhizomes (Curcuma longa) belongs to the family Zingiberaceae and has long been used traditionally for centuries as a spice and medicinal elixir. Hence, the present study aimed to profile the nutritional and phytomedicinal proper- ties of the plant in order to justify its relevance in traditional phytomedicine and advocate its application in novel pharmacological products. Using standard methods (High Performance Liquid Chromatography, Gas Chromatography Mass Spectroscopy and Atomic Absorption Spectrophotometry), the dried rhizomes were washed, pulverized and ethanol extracts subjected to proximate, phytochemical, vitamins, amino acid and mineral determinations. Data obtained were analyzed using student's t-test in Statistical Package for the Social Sciences version 21. Determined proximate indices indicated moisture content of 9.55 %, carbohydrate (57.30 %), ash (24.70 %), crude fiber (1.12 %), proteins (2.15 %) and fat (5.32 %). Mineral composition analyses showed that C. longa rhizomes had higher contents of calcium, magnesium, potassium and sodium in parts per million (ppm) at 38.68 ± 0.114, 19.75 ± 0.001, 9.20 ± 0.002 and 7.06 ± 0.014 respectively. Amino acid profile revealed the presence of both essential and non-essential types with aspartate and glutamate in higher contents at 9.78 g/100 g and 9.65 g/100 g, respectively. Findings showed also the presence of vitamins A, C and D at 254.5 ± 2.19 mg/kg, 19.47 ± 0.16 mg/kg and 10.92 ± 0.92 mg/kg, respectively. Phytochemical analyses showed the presence of phenolic compounds with high retention times. This study thus revealed that C. longa possesses various nutritional and pharmacological/medicinal components in considerable quantities and can provide the body with basic nutrients for its therapeutic needs as well as secondary compounds with tremendous phytomedicinal potentials.

The aim is to study the GC-MS, Proximate analysis, and antimicrobial properties of oil extract from turmeric rhizomes and the objectives are; to collect, identify and prepare Turmeric rhizome sample, to carry out proximate analysis of turmeric rhizome, extract volatile oil from turmeric rhizomes using Soxhlet extraction, characterize the extracted oil using Fourier-transform infrared spectroscope FTIR, identify the volatile chemical constituents in the oil extract from turmeric rhizomes using Gas Chromatography-Mass Spectrometry (GC-MS) and to carry out the antimicrobial studies on turmeric oil extract.

2.0 MATERIALS AND METHODS

2.1 Materials and Equipment

Materials used during the experiment were black cumin seeds, local varieties: Eden and Dirshaye, hexane (99.9 %), sodium hydroxide (99 %), potassium hydroxide (85 %), hydrochloric acid, Gallic acid, saturated sodium carbonate, acetone, phenolphthalein, filter paper, distilled water. All the chemical and reagents were analytical graded from Sigma Aldrich Company limited.

The equipment used include; soxhlet extractor, chiller, rotary evaporator, centrifuge, condenser, oven, viscometer, flask, beaker, Distiller, balance, dissector, test tube, FTIR, GC-MS, muffle furnace, kejaldhal, sieve.

2.2 Experimental methods

2.2.1 Sample Collection and Identification

Tumeric rhizomes (*Cucuma longa*) was collected from a farm at Kujama Chukun Local Government of Kaduna State. The rhizome was removed from the farm dust, stones and other foreign materials removed by hand in order to obtain the pure rhizomes.

The rhizome was identified and authenticated at the herbarium unit of the department of Biological Science, Kaduna State University, Tafawa Balewa way Kaduna.

2.2.2 Sample Preparation

The rhizome was sliced into pieces and dried for 6 days under room temperature and further dried in an oven at 500 °C for 18 hours. The dried rhizome was milled into powder (5 mm) and stored in a polythene bag at room temperature.

After the moisture was removed by placing in an oven at 50 °C for 18 hours, the dried rhizome was pounded to a size of 3 mm. This particular size range was selected because literature revealed that to have a higher yield of oil particle size should be less than 5mm and higher than 0.2 mm (Henry, 2020).

2.2.3 Oil extraction

Experimental work was conducted using soxhlet extractions. In the extraction process, hexane was used as a solvent.

Cucuma longa rhizomes sample was placed in the thimble and inserted in the center of the extractor. The Soxhlet was heated to 60 °C. This was allowed to continue for two, four and six hours. The weight of oil extracted was determined for each run hours. At the end of the extraction, the resulting mixture (essential oil and hexane) containing the oil was heated to recover solvent from the oil, separation of oil from hexane was carried out using rotary evaporator (Lawson *et al*., 2021).

Extraction temperature was chosen to avoid thermal degradation of bioactive compounds and also the temperature is in the range of boiling point of the solvent (Kittiphoom and Sutasinee, 2019). The resulting extracts, obtained under different operating conditions were separated by evaporating the solvents using rotary evaporator in which the setup was established in the laboratory under specific temperature of 70 °C of boiling points of the solvent of hexane. The products were weighed and the oil physicochemical properties was determined. (Kittiphoom and Sustasinee, 2013).

2.2.4 Determination of percentage of oil extracted

The percentage yield was calculated in two forms i.e. oil yield and extraction yield using the formula below,

$$\text{Percentage oil yields} = \frac{\text{Mass of oil X 100}}{\text{Mass of the Sample}} \quad \text{.....(1)}$$

2.3 Proximate Analysis

The standard analytical procedures for food analysis were adopted for the determination of the moisture content, crude protein, crude fibre, percentage lipids, carbohydrate, and ash.

2.3.1 Determination of moisture content

Two grams of the sample were put into the crucibles, dried in an oven at 105 °C overnight. The dried sample was cooled in a desiccator for 30 min and weighed to a constant weight. The percentage loss in weight was expressed as percentage moisture content on dry weight basis (AOAC, 2006).

2.3.2 Determination of ash content

From the dried and ground sample, 2.00 g was taken in triplicates and placed in pre-weighed crucibles and ashed in a muffle furnace at 600 °C for 3 hrs. The hot crucibles were cooled in a desiccator and weighed. The percentage residual weight was expressed as ash content (AOAC, 2006).

2.3.3 Crude lipid content determination

From the pulverized sample, 2.00 g was used for determining the crude lipid by extracting the lipid from it for 5 hrs with (60 to 80 °C) petroleum ether in a Soxhlet extractor (AOAC, 2006).

2.3.4 Protein determination

Total protein was determined by the Kjedahl method. 0.5 g of the sample was weighed in triplicate into a filter paper and put into a Kjedahl flask, 8 to 10 cm^3 of concentrated H_2SO_4 were added and then digested in a fume cupboard until the solution became colourless. Distillation was carried out with about 10 cm^3 of 40 % NaOH solution. The condenser tip was dipped into a conical flask containing 5 cm^3 of 4 % boric acid in a mixed indicator till the boric acid solution turned green. Titration was done in the receiver flask with 0.01 M HCl until the solution turned red (AOAC, 2006).

2.3.5 Determination of crude fibre

From the pounded sample, 2.00 g was used for estimating the crude fibre by acid and alkaline digestion methods using 20 % H_2SO_4 and 20 % NaOH solutions (AOAC, 2006).

2.3.6 Carbohydrate determination

The carbohydrate content was calculated using the following formula: Available carbohydrate (%), = 100 – [protein (%) + Moisture (%) + Ash (%) + Fibre (%) + Crude Fat (%)] (AOAC, 2006).

2.4 Fourier Transform Infrared (FTIR)

The FT-IR spectrum of the essential oil was obtained using Perkins Elmer Spectrum 65 FT-IR spectrometer and functional groups were determined with the help of IR correlation charts. The IR spectra were reported in % transmittance. The wave number region for the analysis was 4000-400 cm^{-1} (in the mid-infrared range).

2.5 Gas Chromatography-Mass Spectrometry (GC-MS)

The GC-MS analysis was performed as previously described (Mbeje *et al.,* 2020). A Shimadzu GC-MS QP-2010 comprising a gas chromatograph hyphenated to a mass spectrophotometer (MS) and an auto sampler was used for this analysis. A 25 m x 0.25 mm fused silica capillary column coated with CP-Sil5 and film thickness at 0.15 µm was fitted to the gas chromatograph. The carrier gas was helium at 1.2 mL/min. Operating conditions of the MS was: ion source temperature 230 °C. The MS data obtained was processed online with desktop computer fitted with disk memory. The identification of the components was accomplished by comparison of the retention indices, fragmentation pattern and mass spectra with spectrum of known components stored in the database of National Institute for Pharmaceutical Research and Development, Abuja, Nigeria.

2.6 Antibacterial Susceptibility Test

2.6.1 Preparation of the McFarland's standard

One percent (1 %) v/v solution of sulphuric acid was prepared by adding 1mL of concentrated sulphuric acid to 99 mL of water. One percent (1 %) w/v solution of barium chloride was also prepared by dissolving 1 g of dehydrated barium chloride ($BaCl_2.2H_2O$) in 100 mL of distilled water. Approximately 0.5 mL of the barium chloride solution was then added and mixed to 9.5 ml of the sulphuric acid solution to obtain the turbidity standard. A small volume of about 5mL of the turbid solution was transferred to a capped tube of the same type as one that will be used for preparing the test and control inocula (Cheesbrough, 2006).

2.6.2 Inoculum standardization

Cell suspension (inoculum) was prepared by transferring a portion of the fresh growth (24 hrs) with an inoculating loop to the suspending medium (9 mL normal saline). The suspension was then compared with McFarland standard by holding the suspension and the McFarland in front of a light source against a white background with contrasting black lines. Turbidity between the two tubes (test and McFarland) was then compared by reading the newsprint against which they were placed and matched accordingly (Cheesbrough, 2006).

2.6.3 Preparation of the extract's concentration

The crude turmeric oil extract was used as 100 % concentration and further dilution concentrations was prepared at 75 %, 50 % and 25 % by dissolving 0.75 mL in 0.25 mL, 0.50 in 0.50, 0.25 in 0.075 in dimethyl sulphoxide (DMSO) to obtain 100 mg/mL concentration as a stock.

2.6.4 Antimicrobial susceptibility testing using agar well diffusion methods.

The susceptibility test of the turmeric oil extracts was carried out using agar well diffusion method according to Ogochukwu (2011) with little modification. Standardized bacterial culture suspensions (*Staphylococcus aureus, Pseudomonas* aeruginosa and *Aspergillus sp*) were inoculated on the surface of sterile Muller Hinton agar plates by surface streaking using a sterile cotton swab and each bacterium was evenly spread over the entire surface of the agar plate to obtain uniform inoculums.

Five equidistant wells of 6 mm diameter were aseptically prepared in each of the seeded plates using sterile cork-borer. Using a micropipette, 0.2 mL of each of 100 %, 75 %, 50 % and 25 % concentration of the oil extracts was dispensed into each of the corresponding wells, made in the plates. 0.2 mL of 500 mg of liquid ciprofloxacin was used as positive control for bacterial isolates while 0.2 mL 0f 250 mg of ketoconazole was used as the positive control for the fungal isolates. The plates were allowed to stand for 30 min at 4 ^{o}C for pre-diffusion and were then finally incubated at 37 ^{o}C for 24 hours while the fungi plates were incubated at room temperature (26 ^{0}C). Following the incubation, the diameters of the zones of inhibition were measured in mm using transparent meter rule and standard susceptibility range was used to classify zones of inhibition as either sensitive (> 10 mm) or resistant (≤ 10 mm) (Cheesbrough, 2006).

3.0 RESULTS AND DISCUSSION

3.1 Proximate Composition

Proximate composition of turmeric rhizome was carried out to access its nutritional properties. The result obtained from the analysis is shown below

Table 1: Proximate composition of turmeric rhizome sample

Parameter	Composition (%)
Moisture content	10.20
Ash content	6.50
Crude lipid	5.75
Crude protein	8.12
Crude fiber	5.00
Carbohydrate	64.43

Table 1 presents the proximate composition of turmeric rhizome, showing a moisture content of 10.20 %. This finding is consistent with that of Sunday *et al*. (2011) but exceeds the value reported by Ravina *et al*. (2023) at elevated temperatures. Variations in moisture content may be influenced by factors such as temperature, location, sample age, and environmental conditions. The relatively high moisture content suggests a potential susceptibility to spoilage, as foods with high moisture are more perishable. The ash content in this sample is lower than the values reported by both Sunday *et al*. (2011) and Ravina *et al*. (2023), yet it falls within the acceptable range.

The dietary fiber content, recorded at 5.0 %, is slightly higher than values reported by Ravina *et al*. (2023) but lower than those observed by Sunday *et al*. (2011). Dietary fiber is essential for regulating oxidative processes in food and acts as a functional ingredient (Mandalari *et al*., 2010). Additionally, fiber supports digestion, aids in cancer prevention, and helps reduce cholesterol absorption, which is beneficial for managing diabetes (UICC/WHO, 2005; Cust *et al*., 2009).

The sample's crude protein content of 8.12% is marginally lower than that reported by Sunday *et al*. (2011). Crude protein plays a critical role in cellular functions, including acting as enzymatic catalysts and regulating growth and cell differentiation (Whitney and Rolfes, 2005). The sample also showed a crude lipid content of 5.75 %, which is vital for the energy contribution of food substances. Carbohydrates made up 64.43 % of the turmeric rhizome, indicating a substantial energy source, especially since adults require approximately 400–500 g of carbohydrates daily as starch. This carbohydrate content is higher than that reported by Ravina *et al*. (2023).

3.2 Percentage oil yields

The percentage yield of rhizomes oil was determined by Equation

$$\text{Oil Yield \%} = \frac{W1}{W2} \times 100$$

$$\text{Oil Yield \%} = \frac{0.9}{50} \times 100$$

Oil yield (%) = 1.8 %

The essential oil yield from 50 g of plant material, extracted via the solvent method at 60 °C, was calculated to be 1.8 % (V/W). A similar yield was reported for *Boswellia dalzielii*, which produced 1.25 % essential oil (Kubmarawa *et al*., 2011). Essential oil yield can vary depending on factors such as the site and timing of collection, plant part and form, and the extraction method used (Baser *et al*., 2010). Characterization of essential oil from turmeric was conducted using FTIR and UV-Vis spectroscopy. FTIR, particularly effective for analyzing fats and oils, provides information on carbonyl and polar compounds. The FTIR and UV-Vis results were then compared to findings from existing literature.

3.3 UV-Visible spectroscopy

The result of the characterization of the extracted turmeric oil using UV-Visible spectroscopy is shown below

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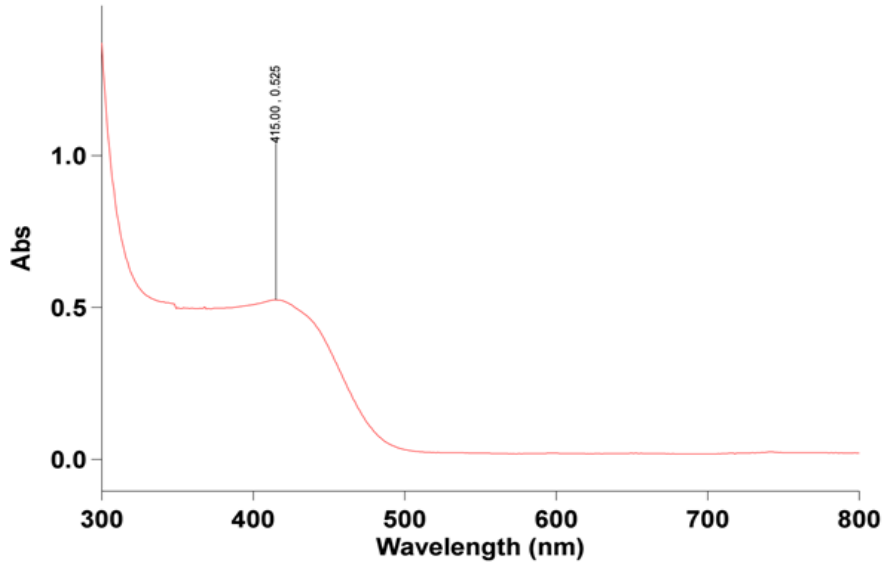

Figure 2: UV-Vis. Spectrum of turmeric oil

The UV-Vis spectrum of turmeric oil shows a single absorption peak at 415 nm with an absorbance of 0.525 and a threshold of 0.0100. This spectrum was observed within a wavelength range of 300–800 nm. An absorption at 415 nm generally indicates the presence of a chromophore, which is a functional group or molecule that contributes to color. Possible structures corresponding to this wavelength include:

1. Conjugated systems, such as polyenes, polyynes, or cumulenes.
2. Aromatic compounds, like phenolic, aniline, or azo-based structures.
3. Heterocyclic compounds, including pyridine, quinoline, or porphyrin derivatives.
4. Biomolecules, such as chlorophyll, heme, or cytochrome c.
5. Transition metal complexes involving metals like copper, iron, or nickel.

A study in *Food Chemistry* found that Curcuma longa extracts, like turmeric oil, show a UV-Vis absorption peak around 420 nm, attributed to curcuminoids such as curcumin. Curcumin's conjugated structure and phenolic groups contribute to its color and antioxidant properties. Unlike turmeric oil, which has a single peak at 415 nm, the extracts displayed multiple absorption bands, likely due to additional compounds in the extract, suggesting a broader spectrum from a more complex mix of bioactive components.

3.4 FTIR

The importance of FTIR techniques as a characterization tool cannot be over emphasized. Hence, this research explores the technique to obtain information about the functional groups present in the extracted oil

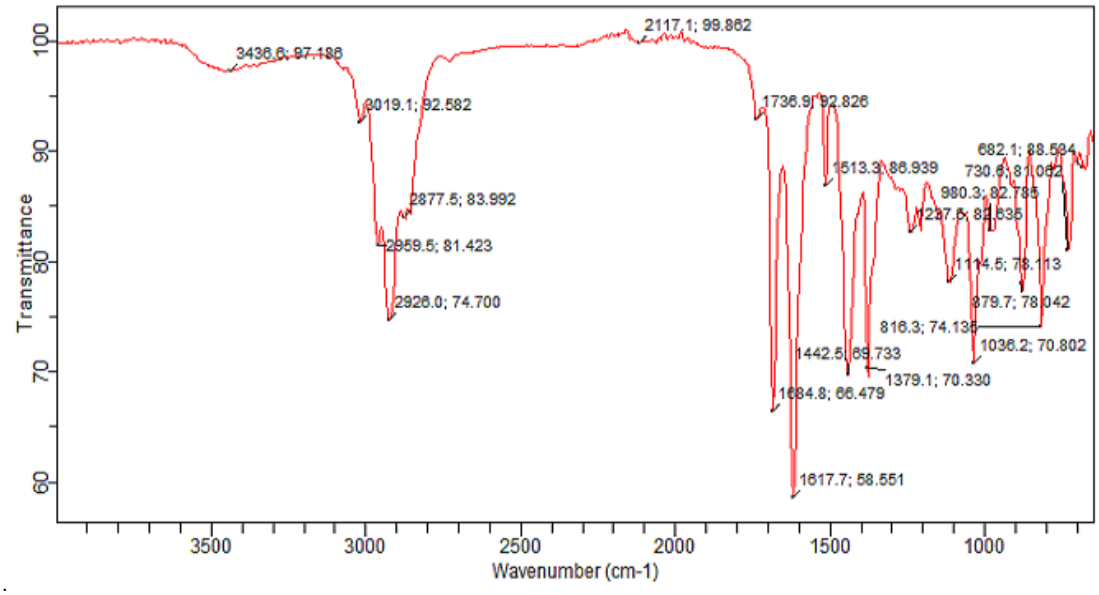

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Figure 3: FTIR of Tumeric Oil Extract

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Table 2: FTIR result for Rhizomes turmeric oil

Wavenumber (cm^{-1})	absorbance	Type of bending and vibration	Wavenumber (cm^{-1})	absorbance	Type of bending and vibration
3436.4	97.186	O–H stretching in Phenolic groups	1442.5	65.733	$-CH_3$ bending of alkane
3019.1	92.582	Aromatic stretch and OH	1379.1	70.330	–C–H (CH_3) Bending symmetric
2959.5	81.423	asymmetric stretching of $-CH_3$	1237.6	82.635	C-O stretching
2926.0		C-H asymmetric stretching of alkane	1114.5	78.113	C=O stretching
2877.5			1036.2	70.802	S=O stretching in sulfur oxide
2117.1	99.862	C≡C of monosubstituted compound	980.3	82.785	Aromatic H
1736.9	92.826	–C=O (ester) Stretching	879.7	78.042	Aromatic H
1684.8	66.479	–C=O stretching in COOH	816.3	74.135	Aromatic H
1617.7	58.551	C=C stretching	730.6	81.062	C=C bending
1513.3	86.939	N-O stretching in Nitro group	682.1	88.534	Benzene derivative

The FTIR analysis results for oil indicate key peaks at various wavelengths, revealing the presence of functional groups such as O-H, C-H, C=O, O-C, =C-H, CN, and N-H, with stretches between 4000 and 650 cm^{-1}. For turmeric oil, FTIR analysis was conducted using an Agilent Technologies machine with a range of 650 to 4000 cm^{-1}. Significant peaks include a broad spectrum at 3436.4 cm^{-1}, indicating triglycerides and assigned to the O-H stretch of phenolic and alcohol groups. A peak at 3019.1 cm^{-1} corresponds to the O-H and –OOH- stretch of hydroperoxide groups as oxidative products, as noted by Ogbu and Ajiwe (2016). The absorbance increased between 3029.1 and 3436 cm^{-1}, with a peak at 2959.5 cm^{-1} linked to the asymmetric stretch of a methyl ($-CH_3$) group in an alkyl saturated aliphatic structure (Yahaya *et al.*, 2019). Irnawati *et al.* (2021) reported similar findings in pumpkin seed oils. At 2926.0 cm^{-1}, a sharp peak signifies the asymmetric stretch of methylene ($-CH_2$) in carboxylic acids, supported by Irnawati *et al.* (2020) and Girigisu *et al.* (2023). A C≡C stretch of a monosubstituted compound appears at 2117 cm^{-1}. The absorption band at 1736 cm^{-1} suggests a C-H bending bond of an aromatic compound, while carbonyl absorption between 1617.7 and 1684.8 cm^{-1} shows free and esterified carboxyl groups, with peaks at 1700-1600 cm^{-1} indicating C=O stretching in aromatic rings and unsaturated C=C bonds. In the fingerprint region (1500-650 cm^{-1}), bands between 1560 and 1500 cm^{-1} reflect pyridine-like groups (C=N) and N-O bending of nitro compounds. Peaks at 1442.5 and 1379.1 cm^{-1} indicate C-H bending in alkanes within the turmeric oil ring structure, consistent with Mohammed *et al.* (2016) and Girigisu *et al.* (2023). Bands between 1200-1000 cm^{-1} suggest C=O stretching and S=O stretching in sulfur oxide. Peaks at 980.3 and 879.7 cm^{-1} align with Rohman *et al.* (2010), who noted differences in spectra at 872-850 cm^{-1} due to $=CH_2$ bonds in aromatics. Sharp peaks at 816.3 and 730.6 cm^{-1} correspond to out-of-plane bending vibrations of –HC=CH– (trans) and –HC=CH– (cis), respectively, as noted by Ozulku *et al.* (2017) and Arslan *et al.* (2019), with similar observations by Riyanta *et al.* (2020).

3.5 Gas Chromatography-Mass Spectrometry (GC-MS)

GC-MS has been regarded as a great tool in identifying volatile compounds. With the help of the MS library, bioactive compounds presence in the extracted turmeric oil were identified after their detection at the GC. The obtained result is shown below.

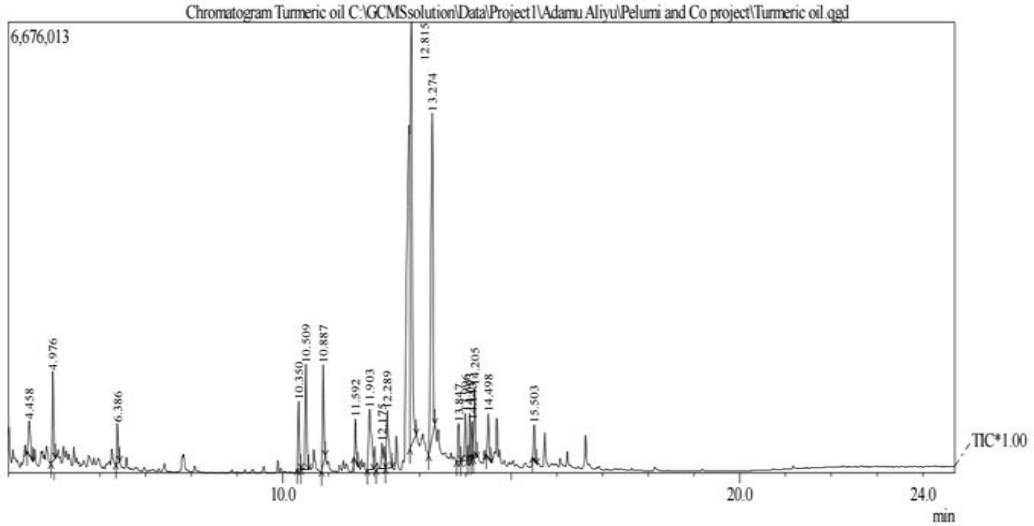

Figure 4: GCMS of Tumeric Oil Extract

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Table 3: GC-MS analysis of essential oils from turmeric Rhizomes

No	RT	Area %	Molecular Wt.	Molecular formula	Name
1	4.458	2.23	134	$C_{10}H_{14}$	Benzene, 1-ethyl-2,3-dimethyl
2	4.976	3.90	156	$C_{11}H_{14}$	Undecane
3	6.386	1.62	170	$C_{12}H_{26}$	Dodecane
4	10.350	2.89	202	$C_{15}H_{22}$	Ar-Curcumene (Benzene, 1-(1,5-dimethyl-4-hexenyl))
5	10.509	4.92	204	$C_{15}H_{24}$	Zingiberene (1,3-Cyclohexadiene, 5-(1,5-dimethyl-4-hexenyl)-2-methyl-)
6	10.887	4.47	204	$C_{15}H_{24}$	β-Cedrene (1H-3a,7-Methanoazulene, octahydro-3,8,8-trimethyl-6-methylene-)
7	11.592	1.83	372	$C_{16}H_{22}Br_2$	p-Menthane, 2,3-dibromo-8-phenyl-
8	11.903	5.74	204	$C_{15}H_{24}$	α-Cedrene (1H-3a,7-Methanoazulene, 2,3,4,7,8,8a-hexahydro-3,6,8,8-tetramethyl-)
9	12.175	2.53	218	$C_{15}H_{22}O$	(+-.)-(E)-Nuciferol (6-(p-Tolyl)-2-methyl-2-heptenol)
10	12.289	4.41	314	$C_{21}H_{30}O_2$	Pregna-3,5-dien-9-ol-20-one
11	12.815	27.05	218	$C_{15}H_{22}O$	Tumerone (2-Methyl-6-(4-methyl-1,3-cyclohexadien-1-yl)-2-hepten-4-one)
12	13.274	23.36	218	$C_{15}H_{22}O$	Curlone
13	13.847	1.87	220	$C_{15}H_{24}O$	7-Oxabicyclo [4.1.0] heptane, 1-(1,3-dimethyl-1,3-butadienyl)-2,2,6-trimethyl-
14	13.996	2.36	204	$C_{15}H_{24}$	α-Bergamotene (Bicyclo [3.1.1] hept-2-ene, 2,6-dimethyl-6-(4-methyl-3-pentenyl)-)
15	14.093	2.13	248	$C_{16}H_{24}O_2$	3-Methyl-2-butenoic acid, 2,6-dimethylnon-1-en-3-yn-5-yl ester
16	14.143	1.62	246	$C_{18}H_{30}$	Benzene, (1,1,4,6,6-pentamethylheptyl)-
17	14.205	3.31	322	$C_{18}H_{26}O_3S$	2-(1,4,4-Trimethylcyclohex-2-en-1-yl) ethyl p-toluenesulfonate
18	14.498	2.11	366	$C_{16}H_{21}F_3O_6$	7,7-Dimethyl-3-oxo-2-oxa-bicyclo [2.2.1] heptane-1-carboxylic acid, 1-ethoxycarbonylmethyl-2,2,2-trifluoromethyl-ethyl ester
19	15.503	1.65	298	$C_{20}H_{26}O_2$	1-Adamantanecarboxylic acid, 3-phenylpropyl ester

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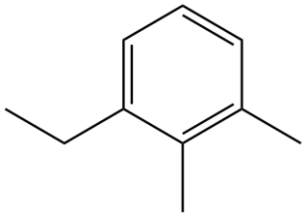

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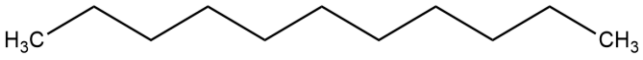

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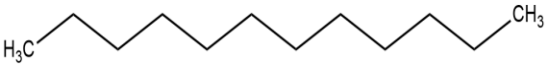

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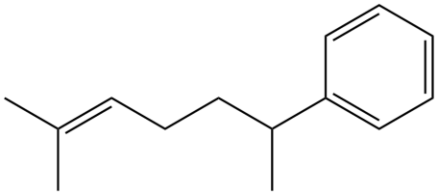
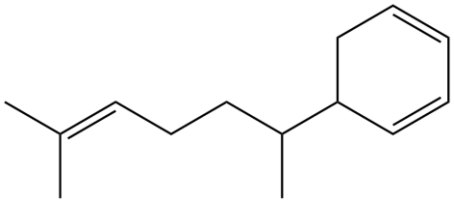
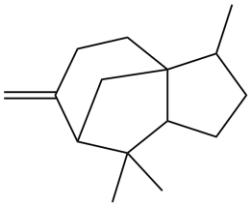


Ar-Curcumene



Zingiberene



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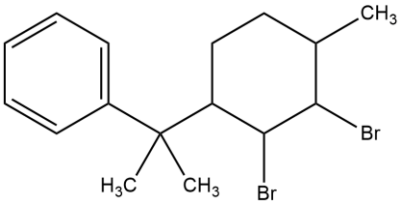

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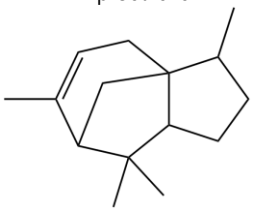
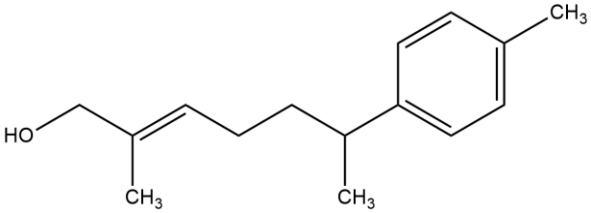
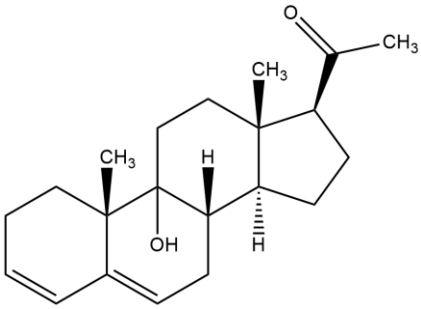


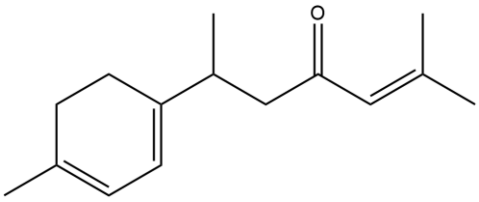
α-Cedrene



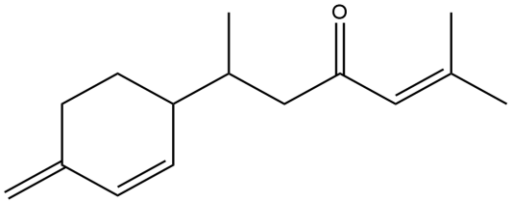
6-(p-Tolyl)-2-methyl-2-heptenol



Pregna-3,5-dien-9-ol-20-one



Tumerone



Curlone

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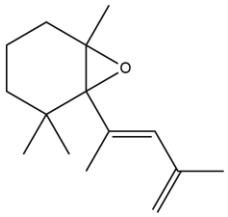
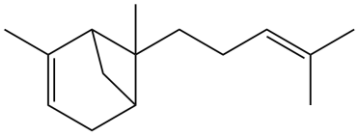
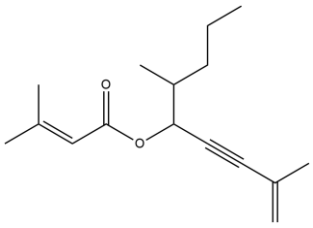


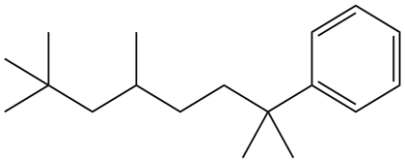
7-Oxabicyclo [4.1.0] heptane, 1-(1,3-dimethyl-1,3-butadienyl)-2,2,6-trimethyl-



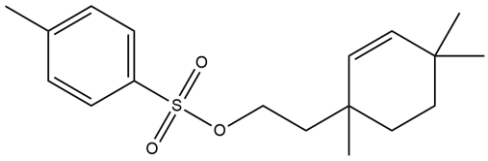
α-Bergamotene



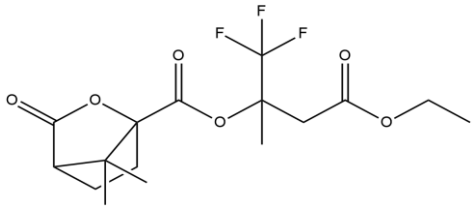
3-Methyl-2-butenoic acid, 2,6-dimethylnon-1-en-3-yn-5-yl ester



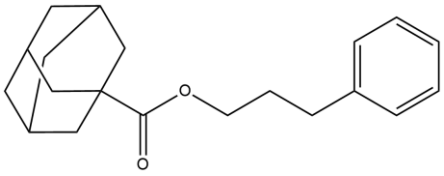
Benzene, (1,1,4,6,6-pentamethylheptyl)-



2-(1,4,4-Trimethylcyclohex-2-en-1-yl) ethyl p-toluenesulfonate



7,7-Dimethyl-3-oxo-2-oxa-bicyclo [2.2.1] heptane-1-carboxylic acid, 1-ethoxycarbonylmethyl-2,2,2-trifluoromethyl-ethyl ester



1-Adamantanecarboxylic acid, 3-phenylpropyl ester

Gas Chromatography-Mass Spectrometry (GC-MS) was employed to identify and quantify essential oil constituents in rhizomes, highlighting specific compounds and their potential bioactive effects. The analysis identified turmerone and curlone as the most abundant components, with notable bioactivity (Kumar *et al*., 2024). The essential oil from the rhizomes contained a total of 19 compounds, with turmerone and curlone comprising 27.05 % and 23.26 %, respectively, consistent with findings by Soumaya *et al*. (2012). The nineteen identified compounds included both oxygenated compounds (52.63 %) and hydrocarbons (47.37 %), as shown in Table 3. Among the oxygenated volatiles, various chemical classes were detected, including esters, ketones, aldehydes, carboxylic acids, and alcohols. Many of these compounds possess pharmacological properties such as antibacterial, antioxidant, anti-inflammatory, and anticancer activities. For instance, ar-curcumene exhibits anticancer and antioxidant effects, while turmerone is known for high antioxidant and antimicrobial properties, making it a potential natural alternative to synthetic food preservatives due to its ability to reduce rancidity.

3.6 Antimicrobial analysis

Antibacterial susceptivity pattern of turmeric oil extract was carried out against some clinical bacterial isolates. The result is shown below

Table 4: Identification and biochemical characteristics of bacterial isolates

Biochemical tests	Isolate 1	Isolate 2
Catalase	+	+
Coagulase	-	+
Citrate	+	+
Indole	-	-
Methyl-Red	-	+
Voges-Proskauer	-	+
Urease	-	+
Shape	Rods	Cocci
Motility	Motile	Non-motile
Probable Organism	*Pseudomonas aeruginosa*	*Staphylococcus aureus*

Key: + = Positive - = Negative

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Table 5: Antibacterial activity of turmeric oil against *S. aureus* and *Psuedomonas sp.*

	Zone inhibition (mm)				Control
	Concentrations (%)				
Bacterial Isolates	100%	75%	50%	25%	Ciprofloxacin (200 mg)
Staphylococcus aureus	25	11	10	26	39
Psuedomonas sp.	11	17	6	-	28

Table 6: Antibacterial activity of turmeric oil against *Aspergillus sp.*

	Zone inhibition (mm)				Control
	Concentrations (%)				
Fungal Isolate	100%	75%	50%	25%	Ketoconazole (150 mg)
Aspergillus sp.	14	9	4	-	28

The cultural characteristics on Mannitol Salt Agar (MSA) and Cetrimide Agar (CA) highlighted distinguishing features of *Staphylococcus* sp. and *Pseudomonas* sp., suggesting possible pathogenic traits. The yellow colonies with surrounding yellow zones on MSA were characteristic of *Staphylococcus* sp., while the large greenish colonies on Cetrimide agar indicated the presence of *Pseudomonas* sp., consistent with findings by Dadashi *et al.* (2016). Susceptibility testing showed that turmeric oil had notable effectiveness at various concentrations against *Staphylococcus aureus* and *Pseudomonas* sp. This antibacterial effect may be attributed to the high saponification value of turmeric oil, potentially facilitating penetration and resulting in larger inhibition zones for both bacterial and fungal isolates. This observation aligns with studies by Al-Tahtawy (2013) and Barret *et al.* (2011), where Gram-negative bacteria showed smaller inhibition zones compared to Gram-positive bacteria.

5.0 Conclusion

The detailed information on nutritional and health promoting components of turmeric rhizome enhances our knowledge and appreciation for the use of it in our daily diet and as a functional food ingredient. Turmeric rhizomes are characterized by high carbohydrate content. The obtained FTIR result revealed the presence of O-H, C-H, C=O, O-C, C-O, =C-H, N-H, and C-N which indicate the functional groups of the compounds present in the essential oils extracted from rhizomes sample. Gas Chromatography-Mass Spectrometer confirmed that the essential oils contained the major components which are expected to be biologically and pharmacologically active. However, the major compounds identified in rhizomes oil were turmerone and curlone. Susceptibility of the isolates revealed significant degree of effectiveness of turmeric oil at different concentrations against the pathogens, this could be related to the activities of the identified compound in the oil.

Availability of data

Data availability is not applicable.

Funding

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Conflicts of interest

No conflict of interest was associated with this work.

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